Focus Topic:
Large-Scale Ice and Ocean Dynamics

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Ice at the Interface

Atmosphere-Ice-Ocean Boundary Layer Processes
June 25-27, 2012 Boulder, Colorado

Focus Topic:
Large-Scale Ice and Ocean Dynamics

There are challenges in understanding the relative importance of tides and inertia, and ocean eddies and narrow currents on surface fluxes in polar seas.

There is a need for suitable metrics to understand and compare models and observations that include these things things, and rheologies suitable for eddy resolving scales.

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Large-Scale Ice and Ocean Dynamics

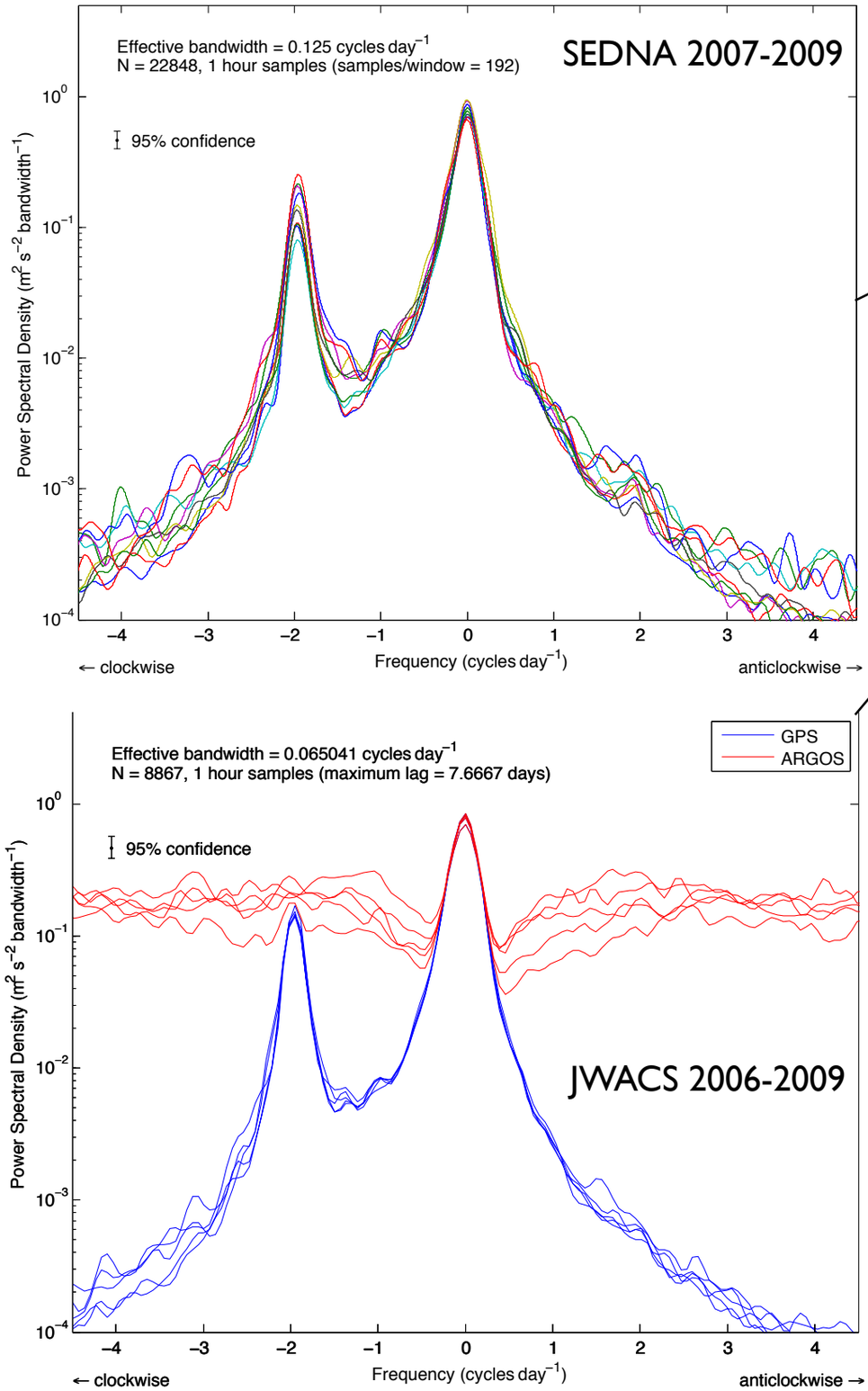
An attempt to clarify some thoughts on sea ice embedding

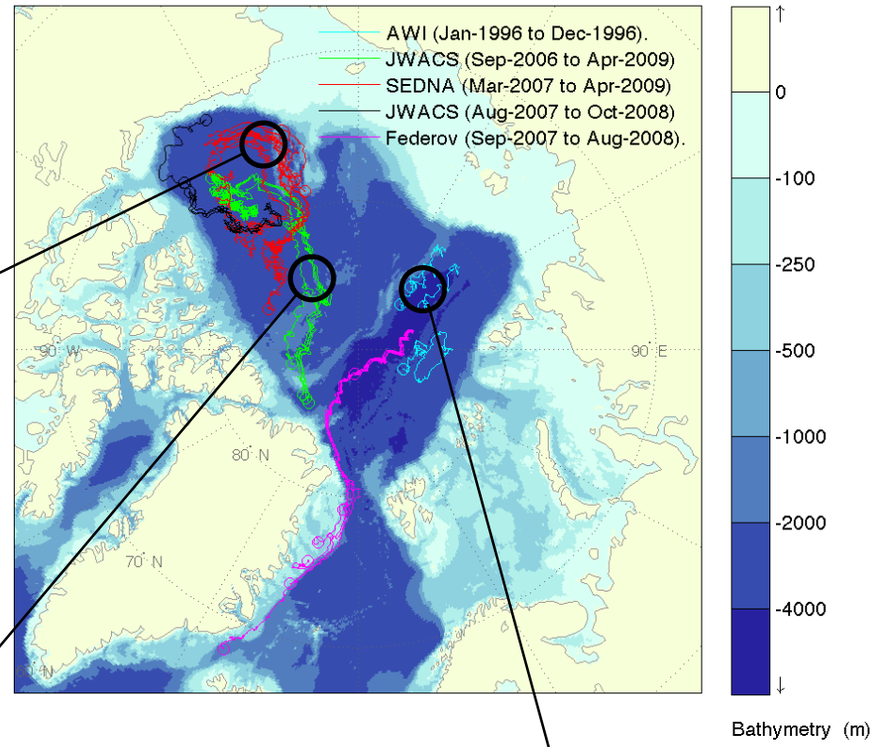
1) Can existing fully coupled models simulate inertial oscillations?

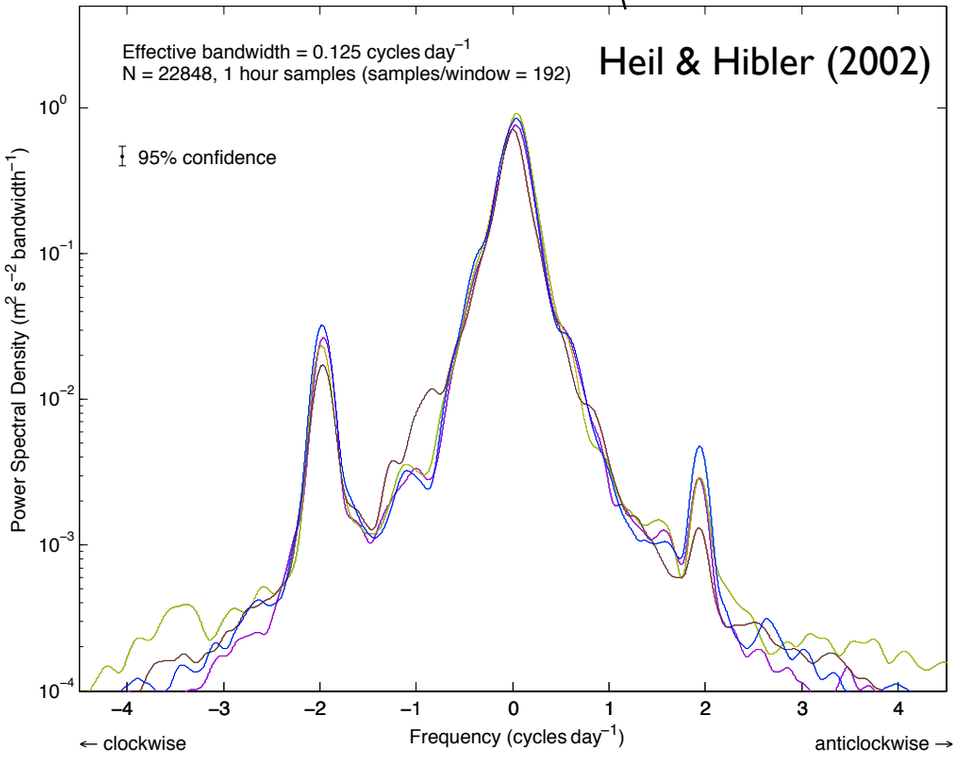
2) What is the impact allowing mass transfer between sea ice and the ocean?

3) How to account for penetration of sea ice into the OBL?

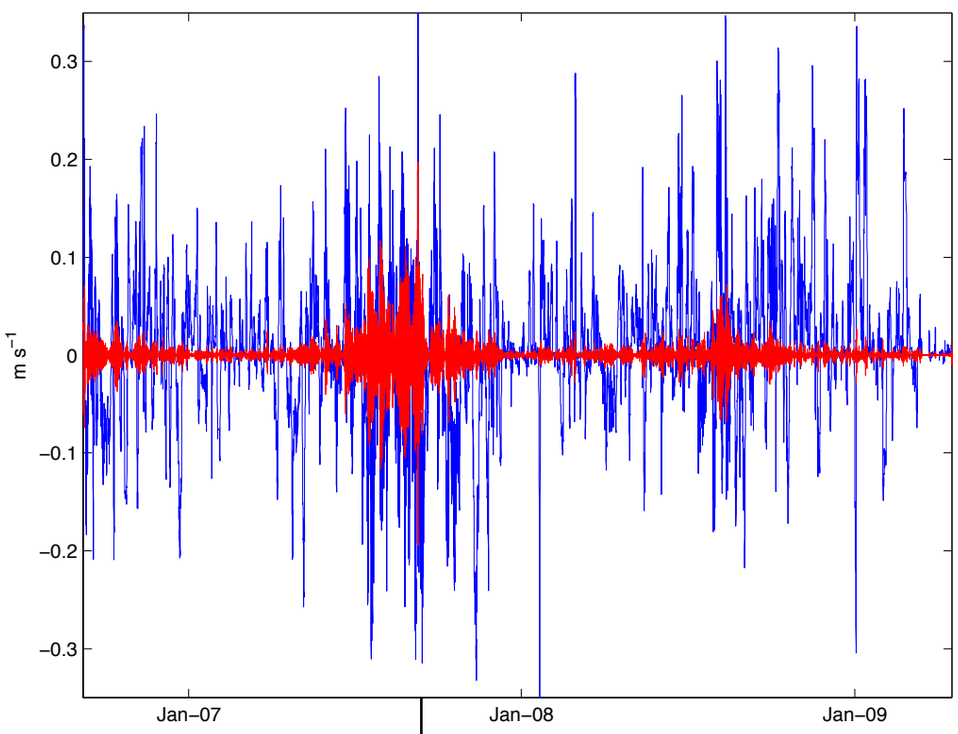
A legacy from IPY 2007-2009

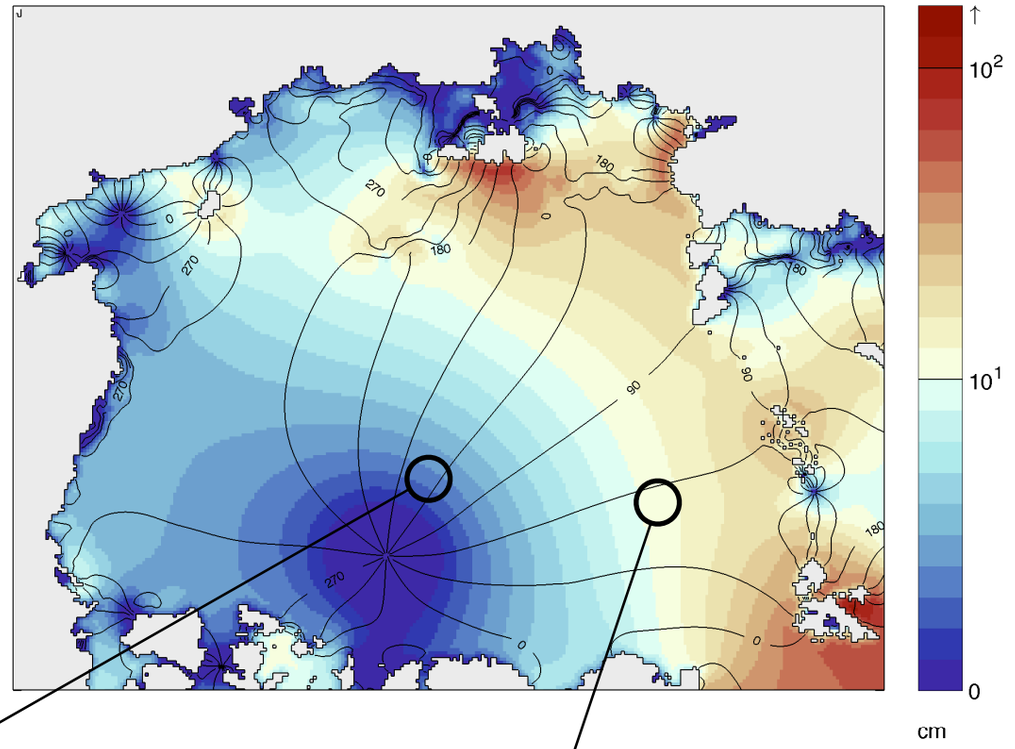


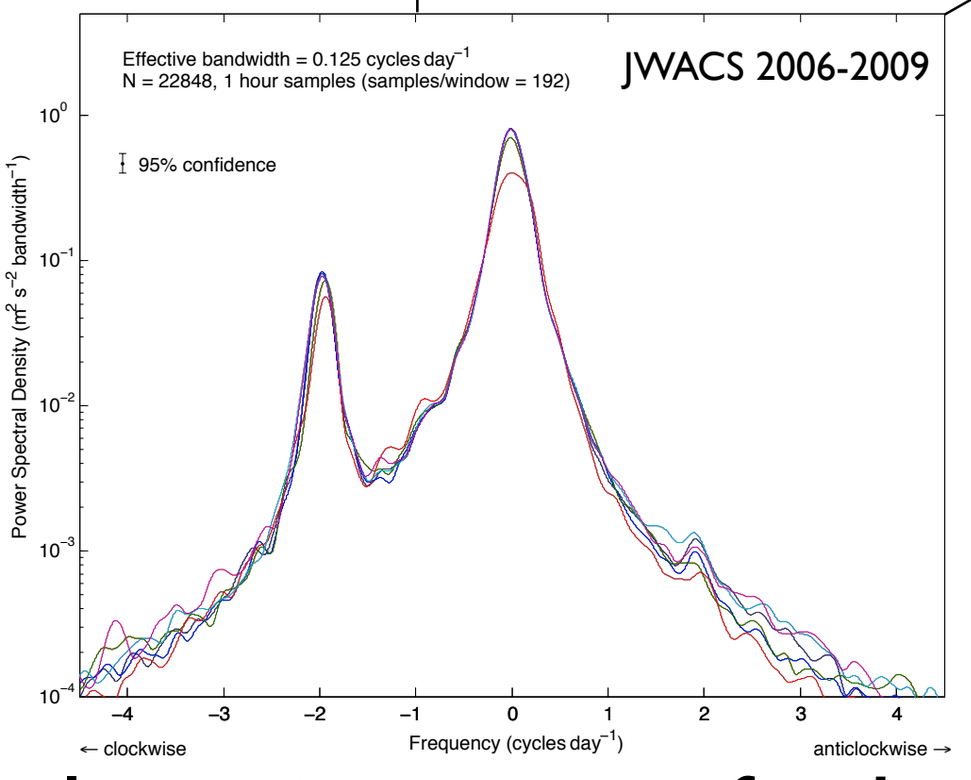


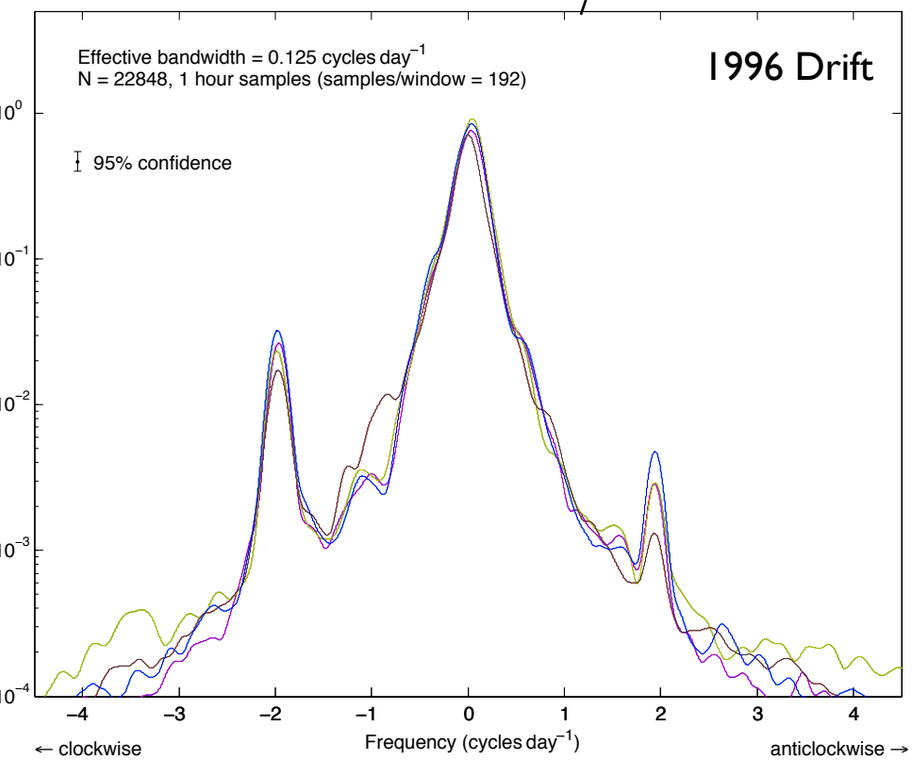


Large-Scale Ice and Ocean Dynamics: Some background



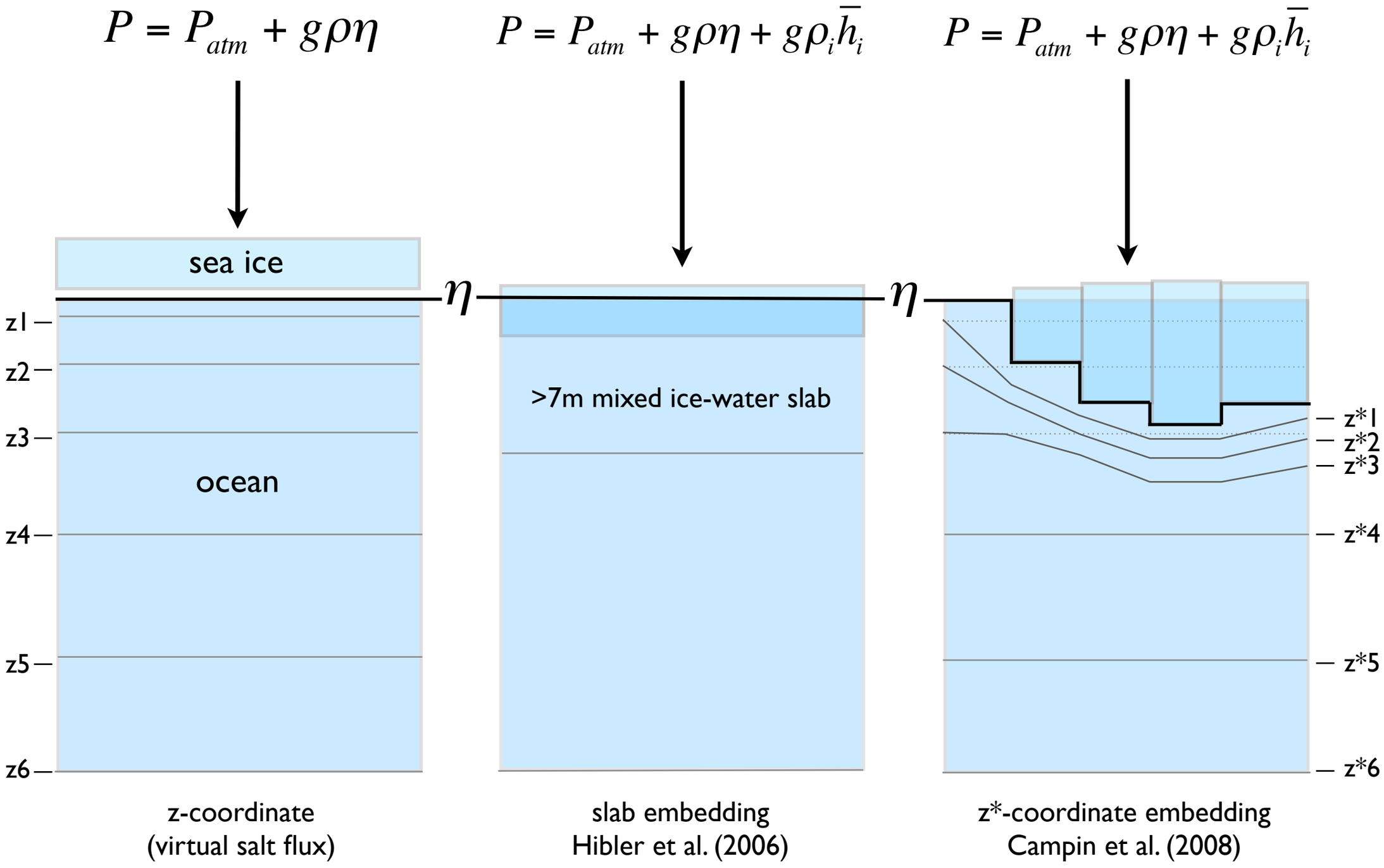






A clear signature of tides and inertia in sea ice drift

Some ways of understanding inertial oscillations

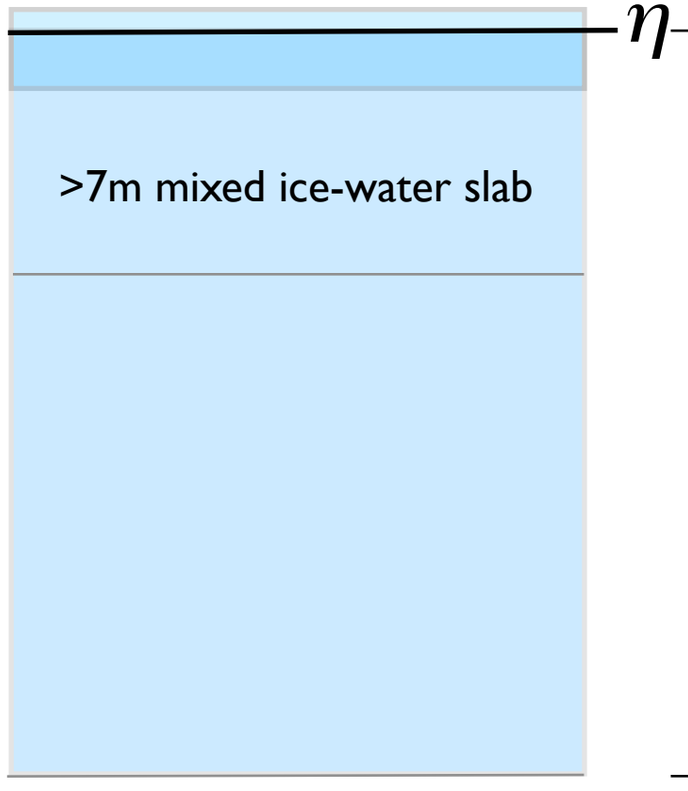


A framework for testing the influence of z* coordinates on sea ice drift

A slab-embedded ice-tide model

$$P = P_{atm} + g\rho\eta + g\rho_i\bar{h}_i$$

$$\underbrace{\frac{\partial \tilde{M}}{\partial t} = \frac{\tilde{\tau}_a}{\rho_{iw}} - f\mathbf{k}\times\tilde{M}}_{\text{LTI System}} + \underbrace{\frac{\partial \sigma_{mn}}{\partial y_n}}_{\text{Non-linear damped forced harmonic oscillator}}$$

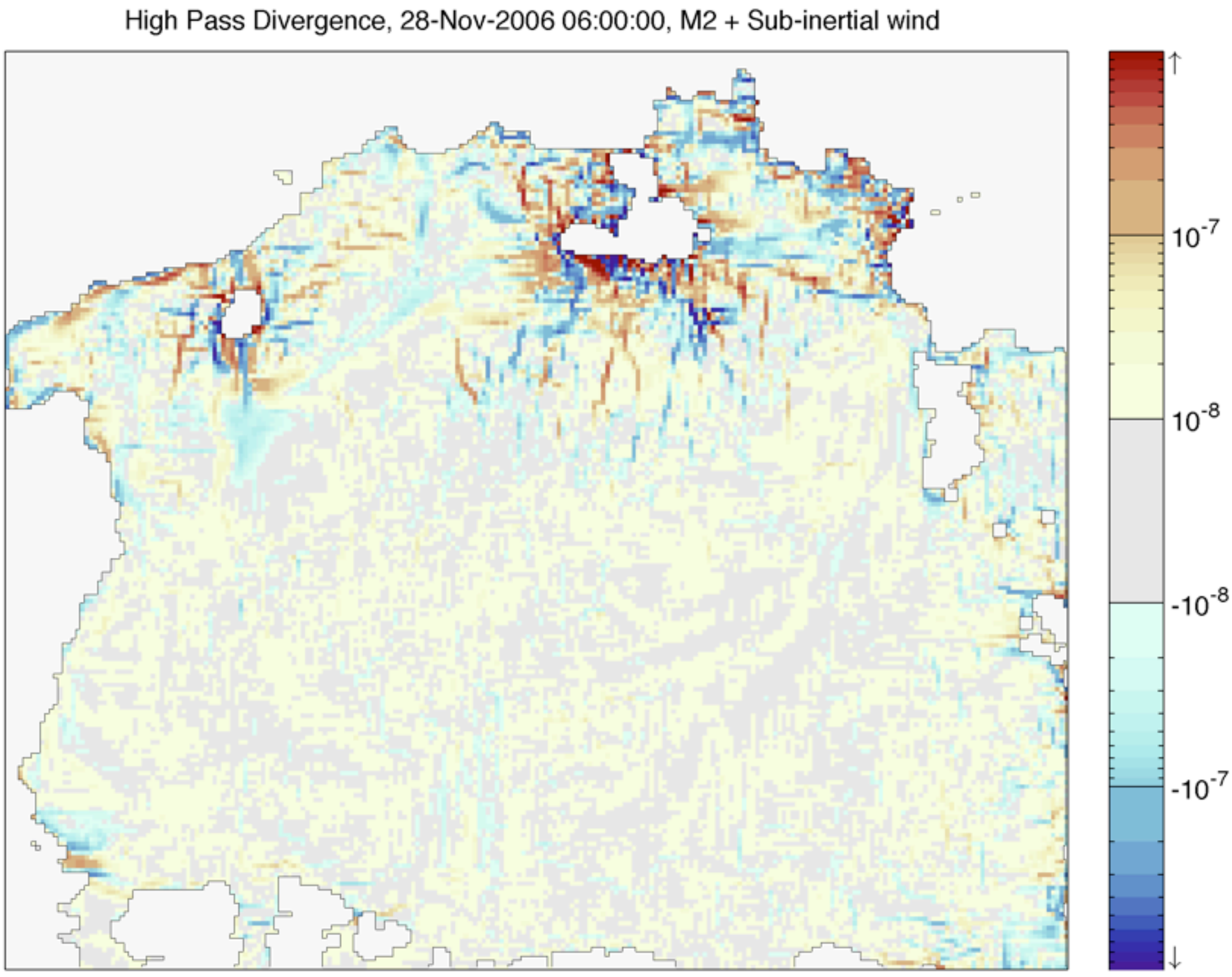


slab embedding
Hibler et al. (2006)

$$\frac{\partial \mathrm{u}}{\partial t} = fe^{-i\pi/2}\mathrm{u} - g\underline{\nabla}\eta + \mu\underline{\nabla}^2\mathrm{u} + \frac{\underline{\nabla}\bullet\underline{\underline{\sigma}}}{\rho_w d} + \frac{\underline{\underline{\tau}}_a}{\rho_w d}$$

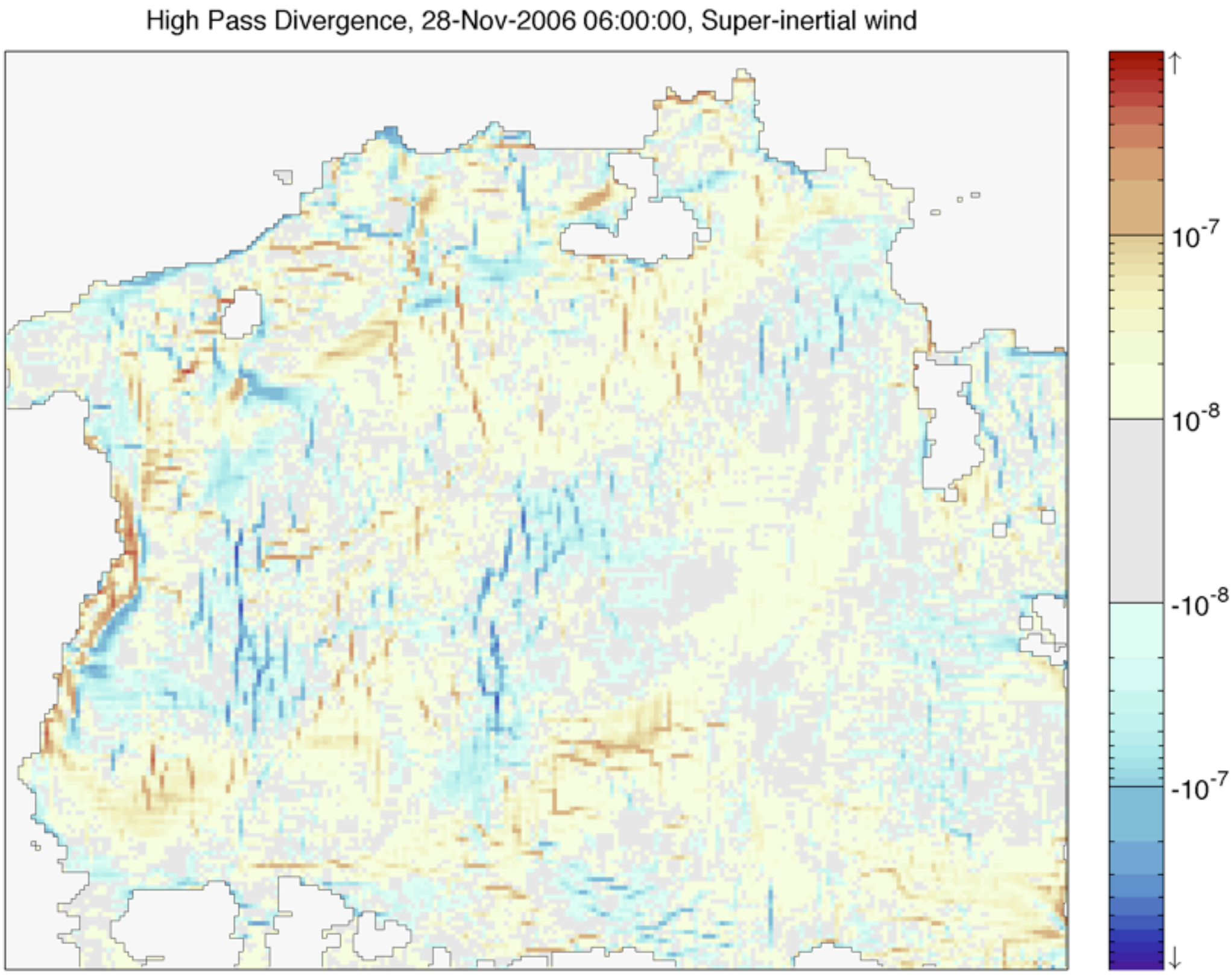
- Linear tidal model
- Surface planetary boundary layer
- Frictionless bottom
- No momentum advection
- Run as “flat-plate” experiments

Deformation for periods of 17 hours or less - M2 tide



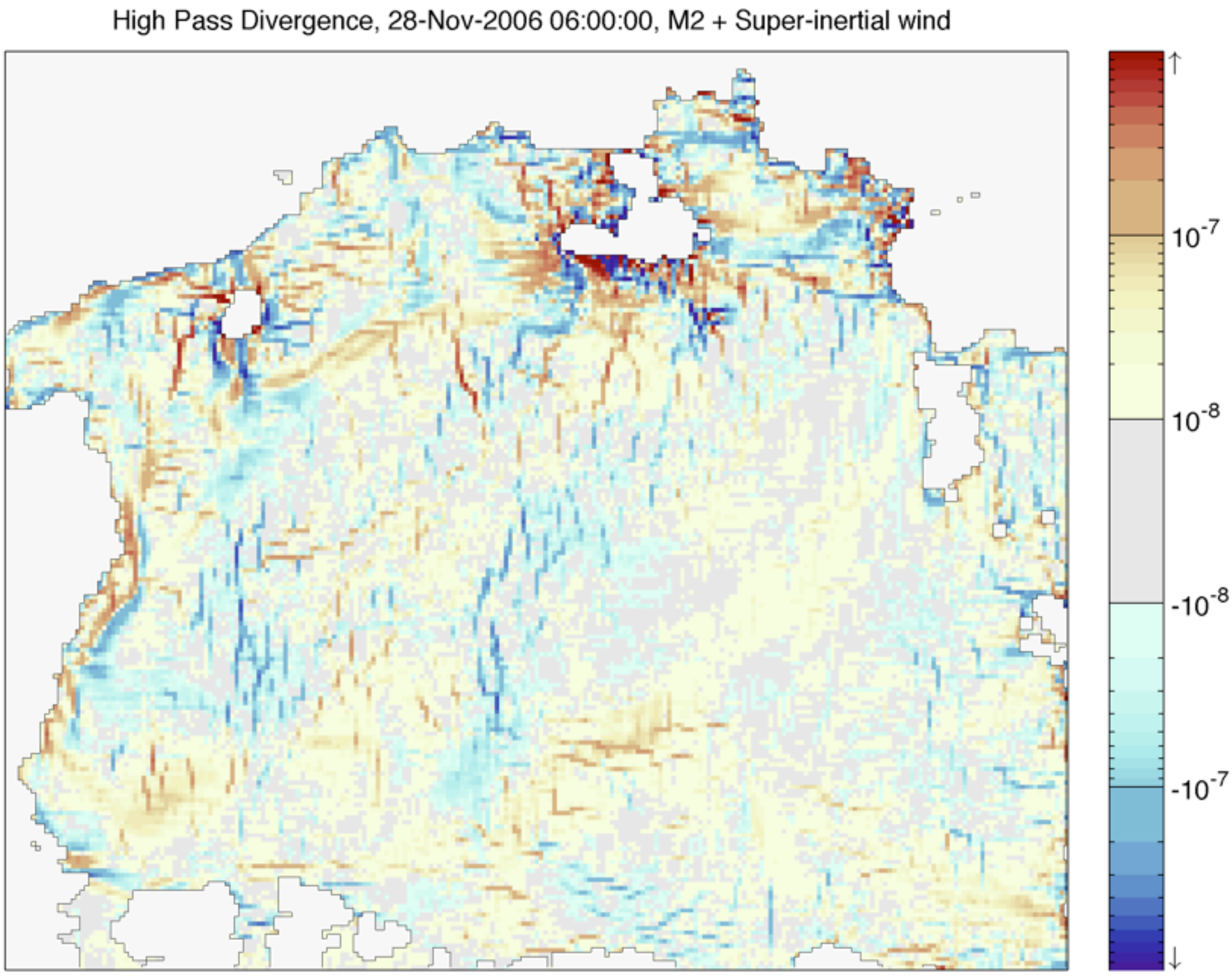
Earlier results: Slab boundary layer testbed

Deformation for periods of 17 hours or less - No M2 tide



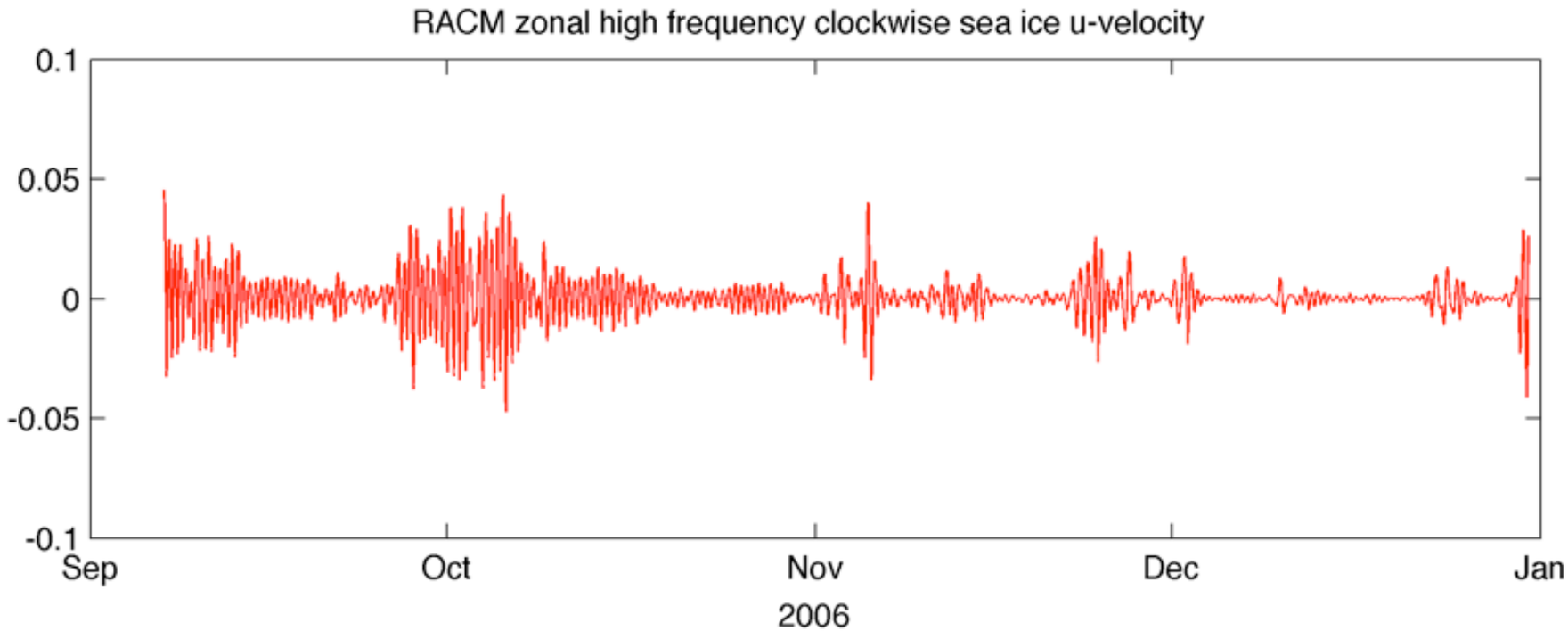
Earlier results: Slab boundary layer testbed

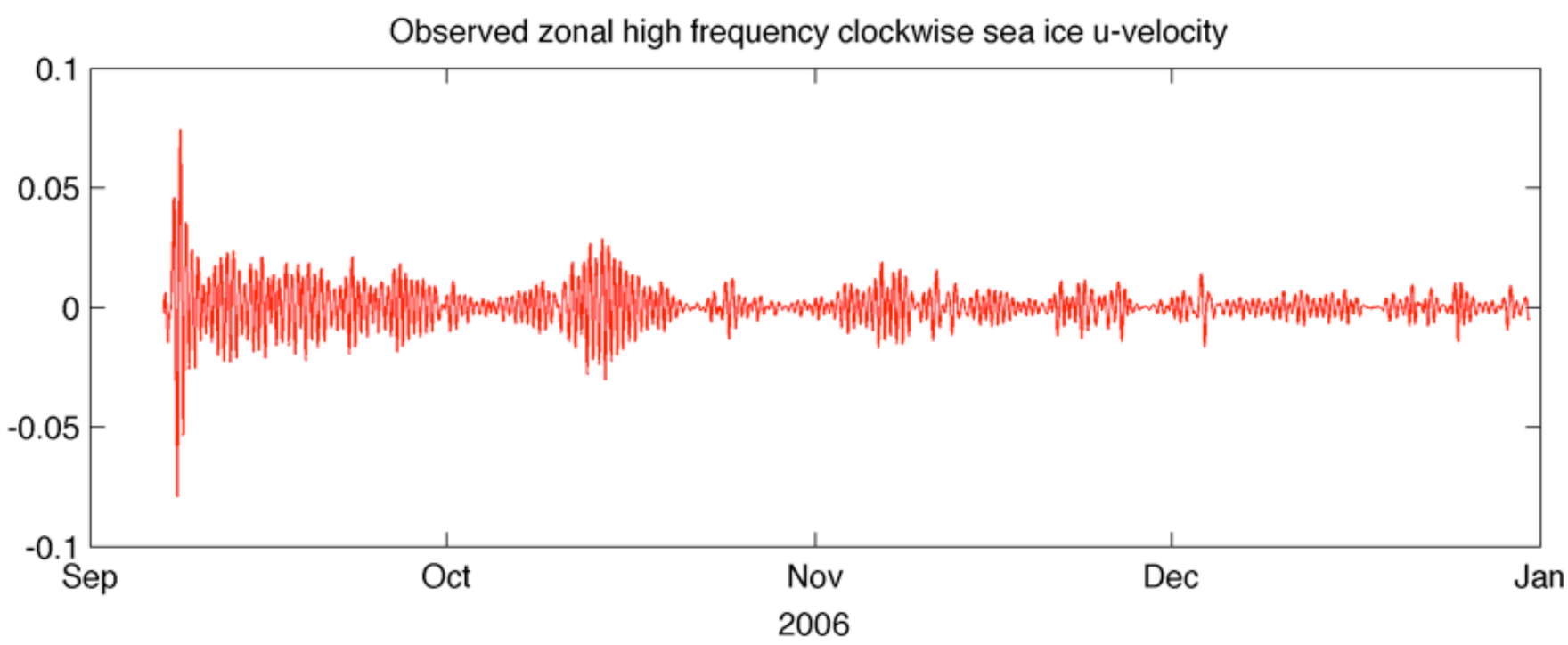
Deformation for periods of 17 hours or less - M2 tide



Earlier results: Slab boundary layer testbed

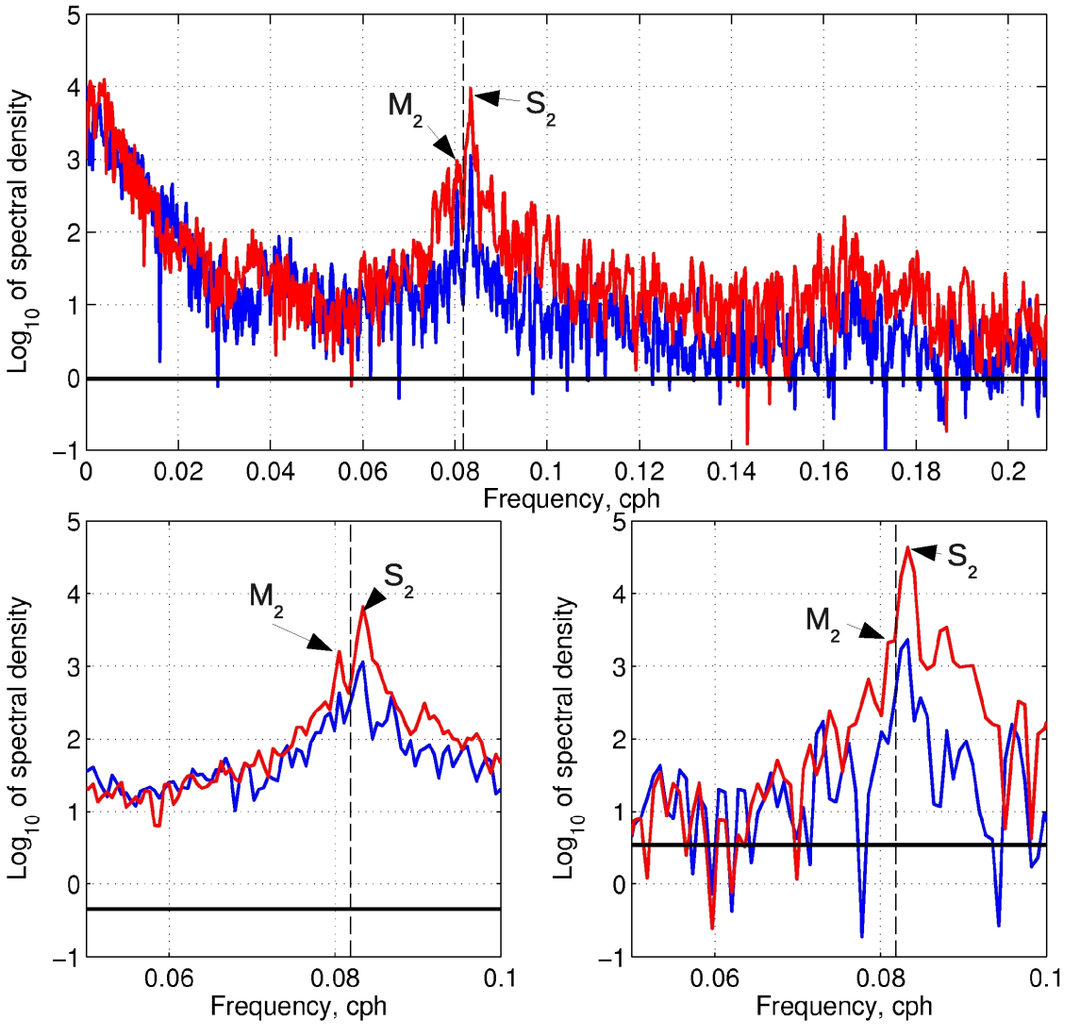
Inertial oscillations in sea ice are a non-stationary process

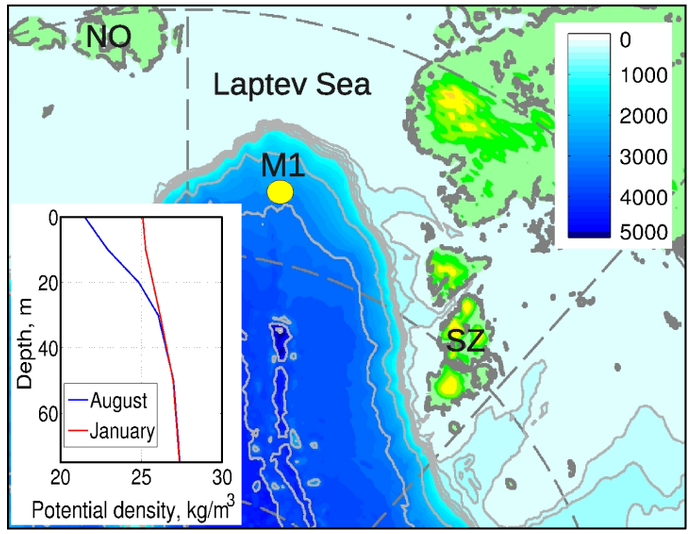




Developing a suitable drift metric

Tidal oscillations in the presence of sea ice are a non-stationary process

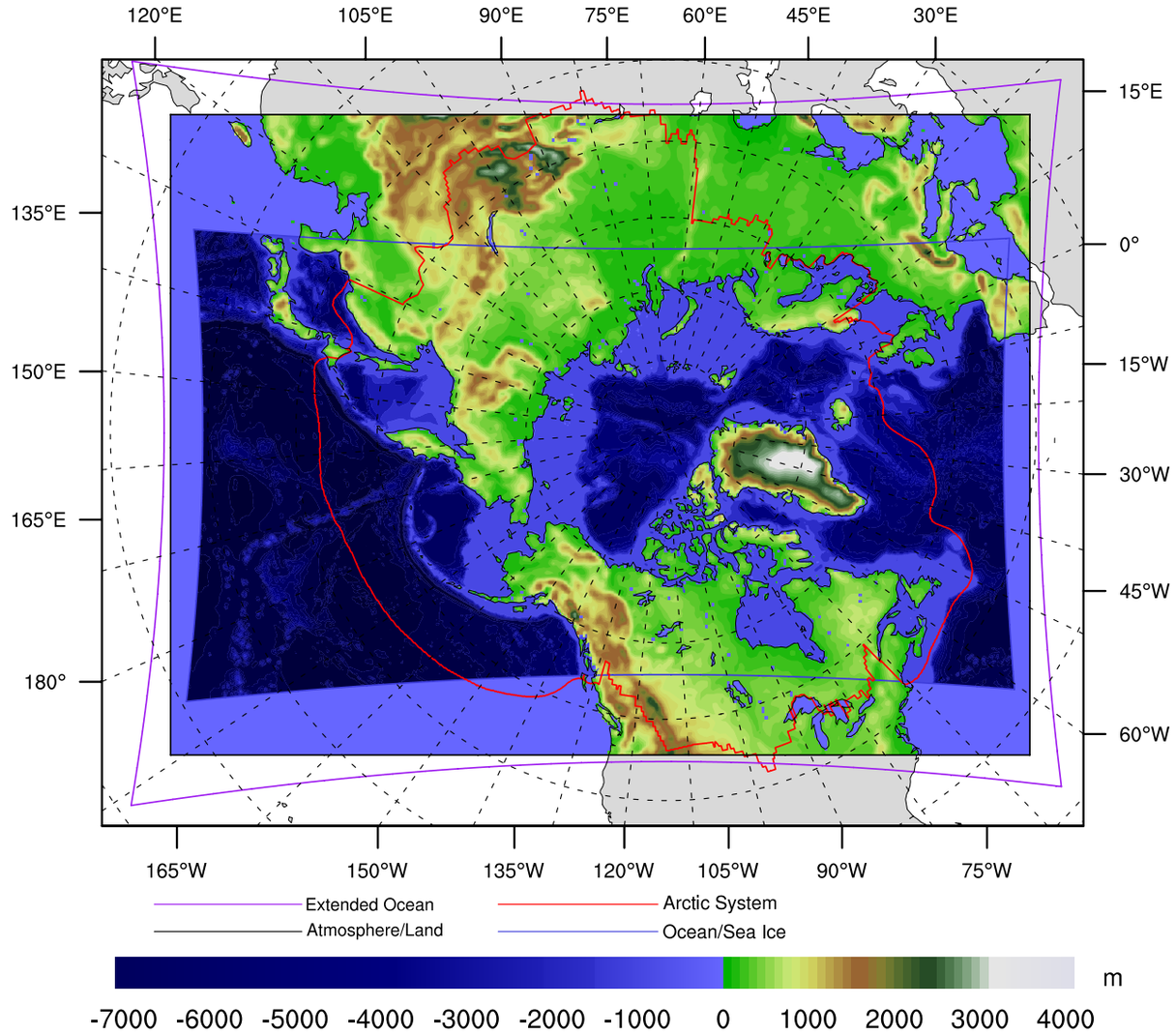




Pnyushkov, A. V., and I. V. Polyakov, 2011: Observations of tidally-induced currents over the continental slope of the Laptev Sea, Arctic Ocean. J. Phys. Oceanogr., 110804064334004.

Large-Scale Ice and Ocean Dynamics: Regional modeling testbed

The Regional Arctic System Model (RASM)



RASM development team: Wieslaw Maslowski, Michael Brunke, John Cassano, Jaclyn Clement-Kinney, Anthony Craig, Alice DuVivier, Brandon Fisel, Jeremy Fyke, Justin Glisan, William Gutowski, Saffia Hossainzadeh, Mimi Hughes, Dennis Lettenmaier, William Lipscomb, Bart Nijssen, Robert Osinski, David Porter, Andrew Roberts, William Robertson, Slawek Tulaczyk, Xubin Zeng

Large-Scale Ice and Ocean Dynamics: Regional modeling testbed

RASM	Model/Code	Configuration
Atmosphere	WRF	50km, 35 levels, dt=2.5mins
Land Hydrology	VIC	50km, dt=20mins
Ocean	POP	9km, 45 levels, dt=8/8/4mins
Sea Ice	CICE	9km, 5cats, dt=20mins
Greenland Ice	CISM	*Implementation in progress*
Coupler	CPL7	20min coupling (2.5 min trials)

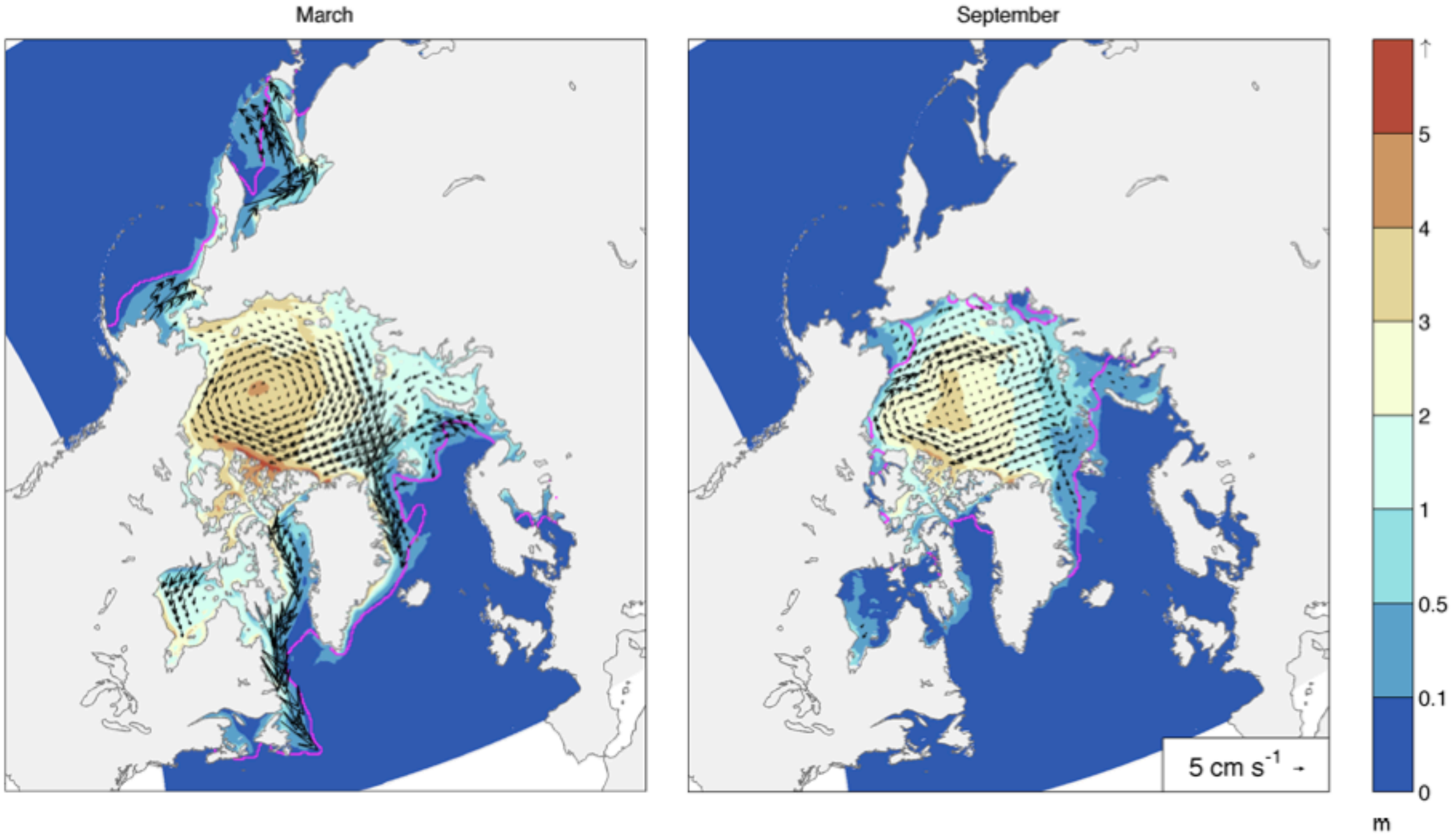
hrRASM		Eddy Resolving
Ocean	POP	2.3km
Sea Ice	CICE	2.3km

Some important reasons for using the CESM framework in a regional setting

- Suitable resolution and runtime for tides and eddies
- Fully coupled atmosphere with 'internal arctic variability'
- Model time corresponds with real 'climate time'

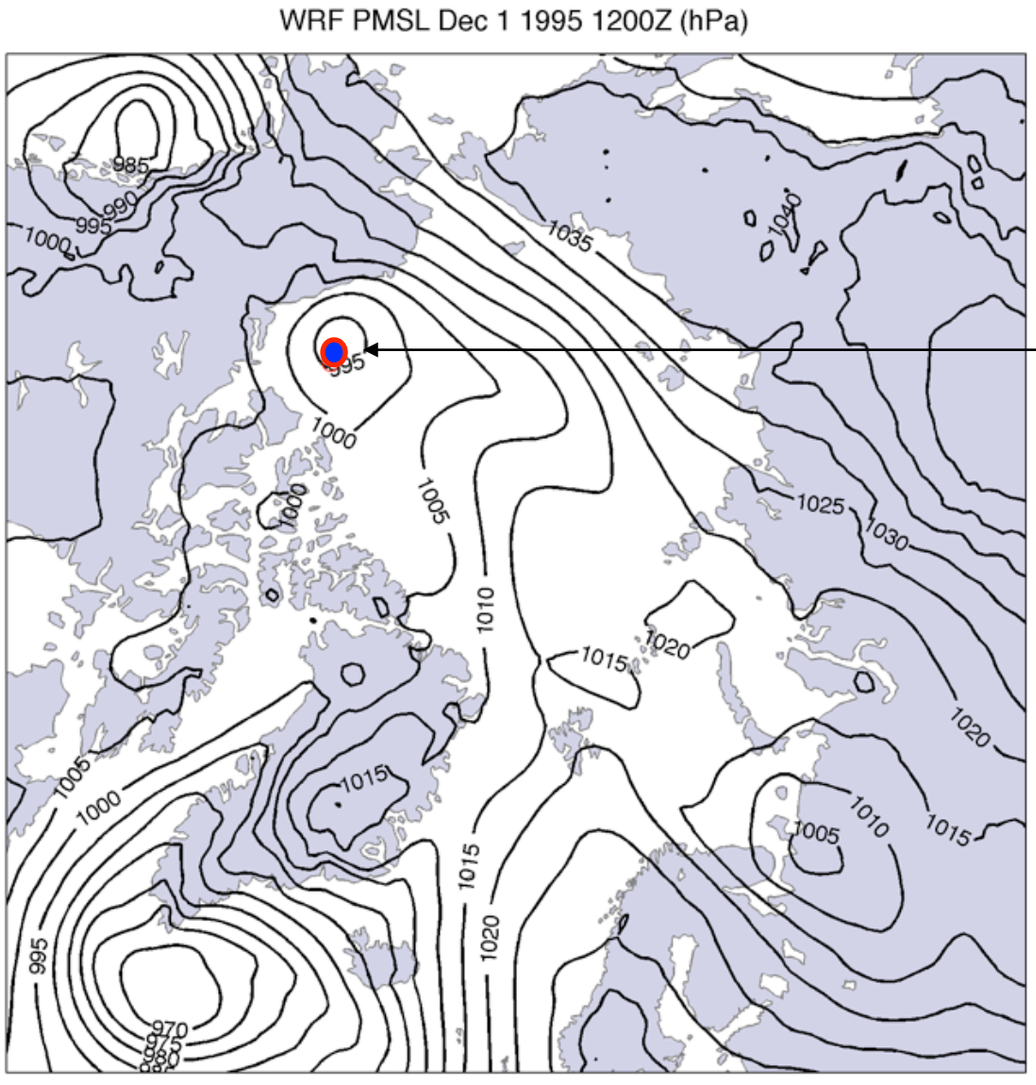
- Scope for coordinated regional and global experiments

Regional model testbed: Basics of RASM

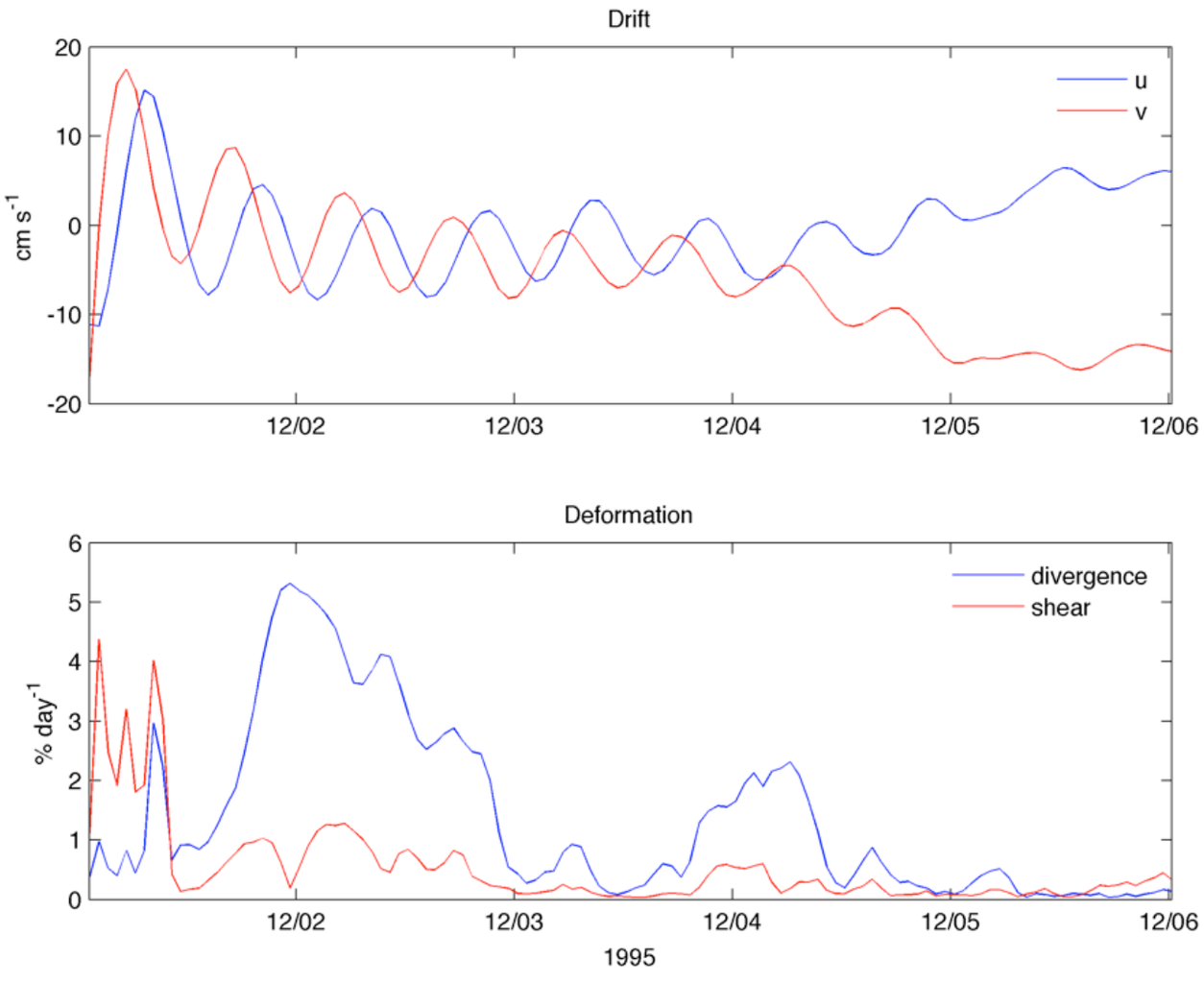


Regional model testbed: The inertia example

Atmospheric State



Ice-Ocean Coupling



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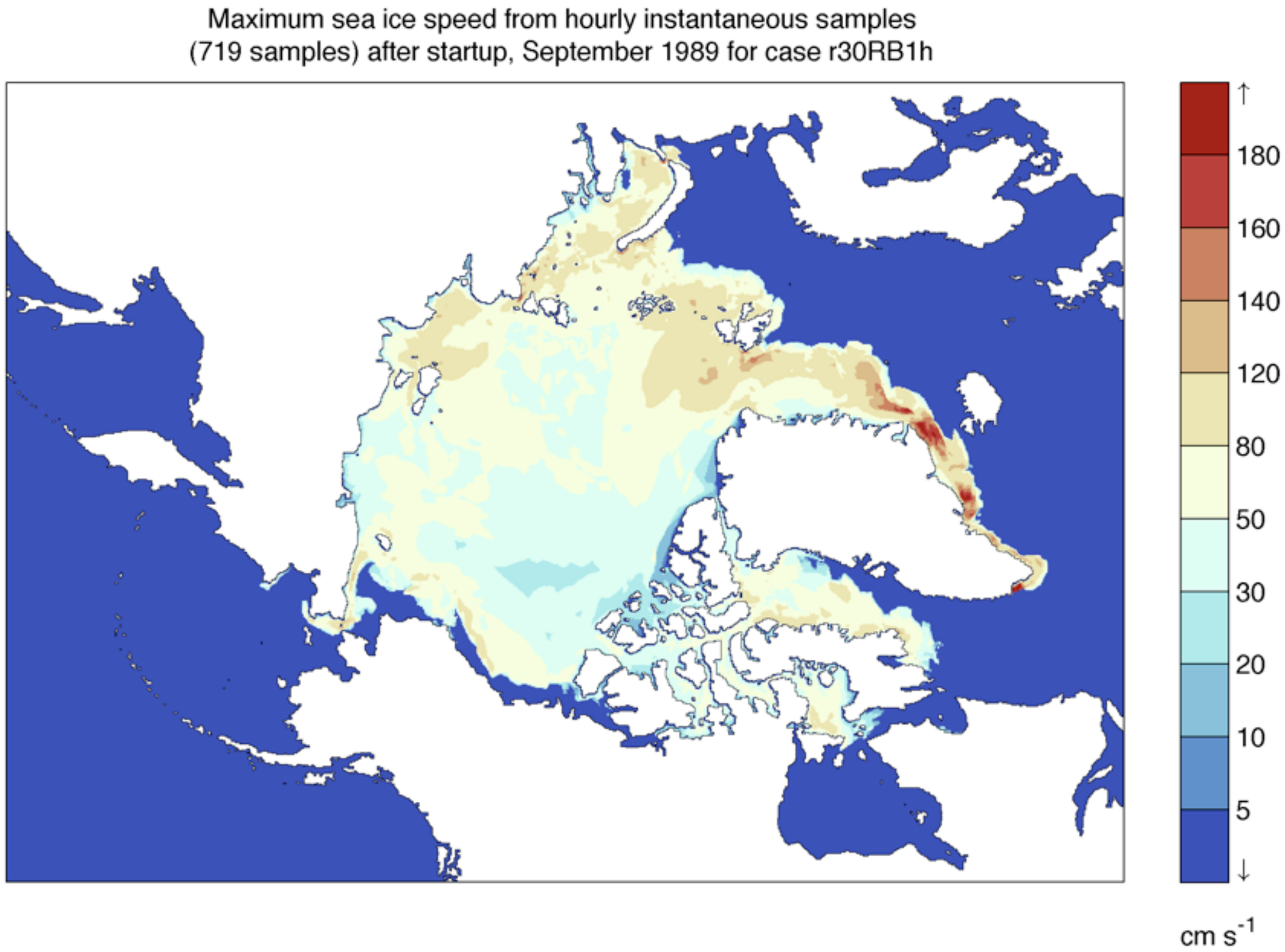
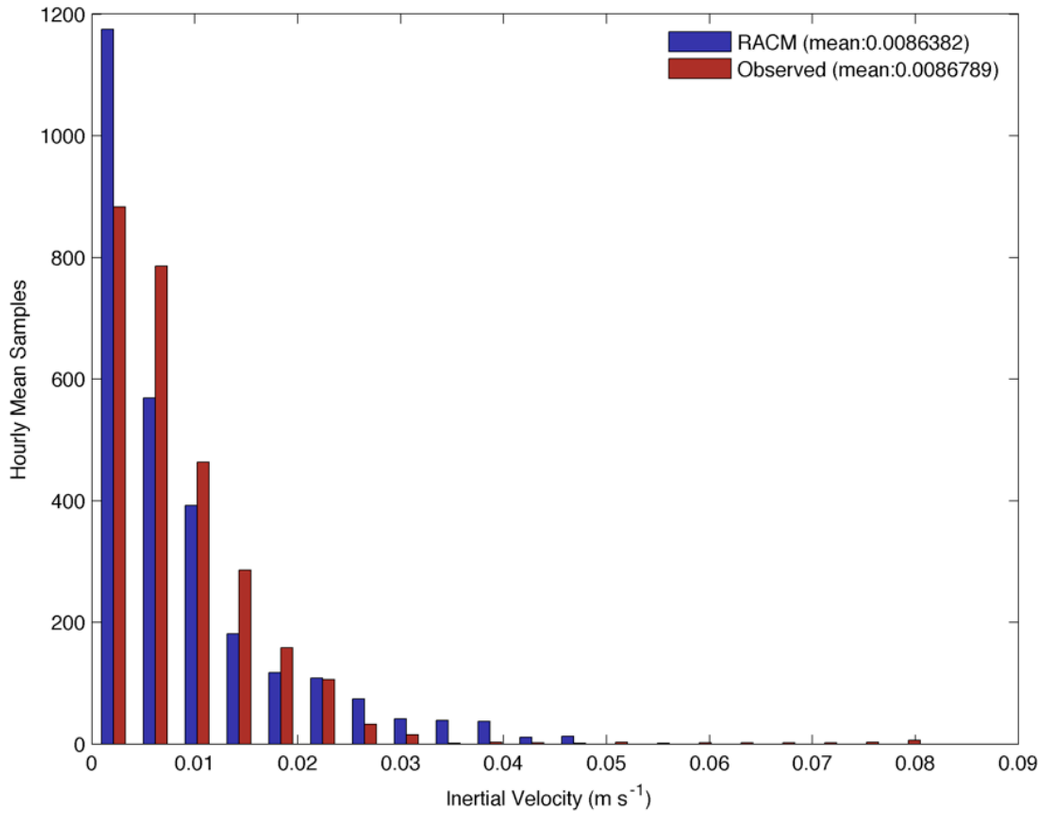
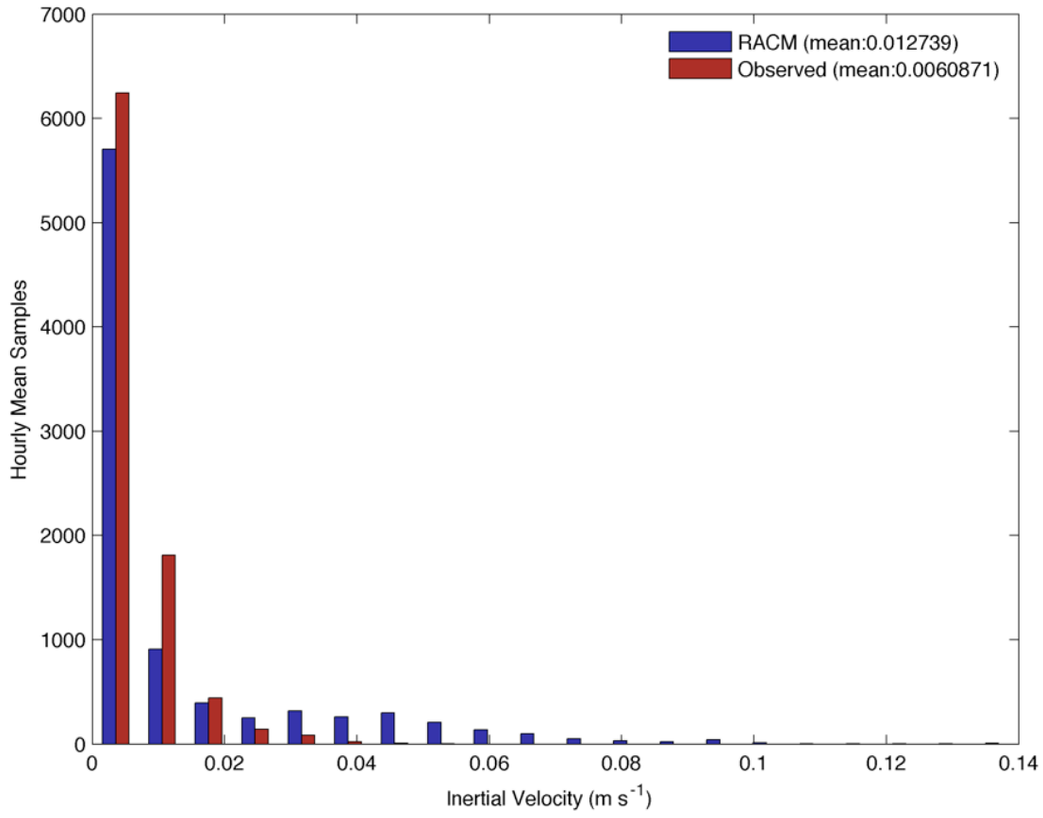


Regional model testbed: The inertia example

Beaufort Sea Sep-Dec 2006



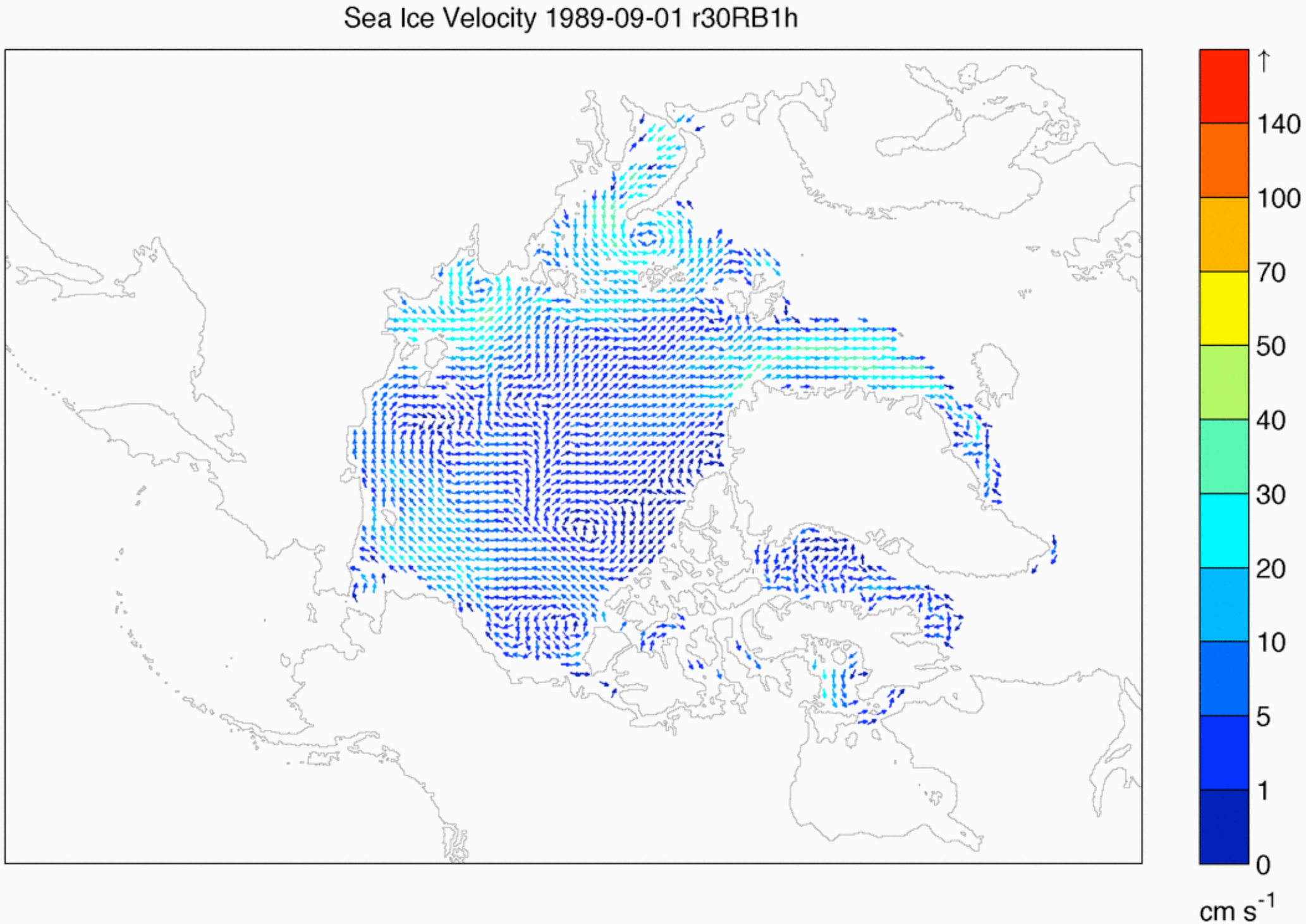
Nansen Basin 1996



From rotary wavelet reconstructions of the clockwise signal 1.5-2.5 cycles/day

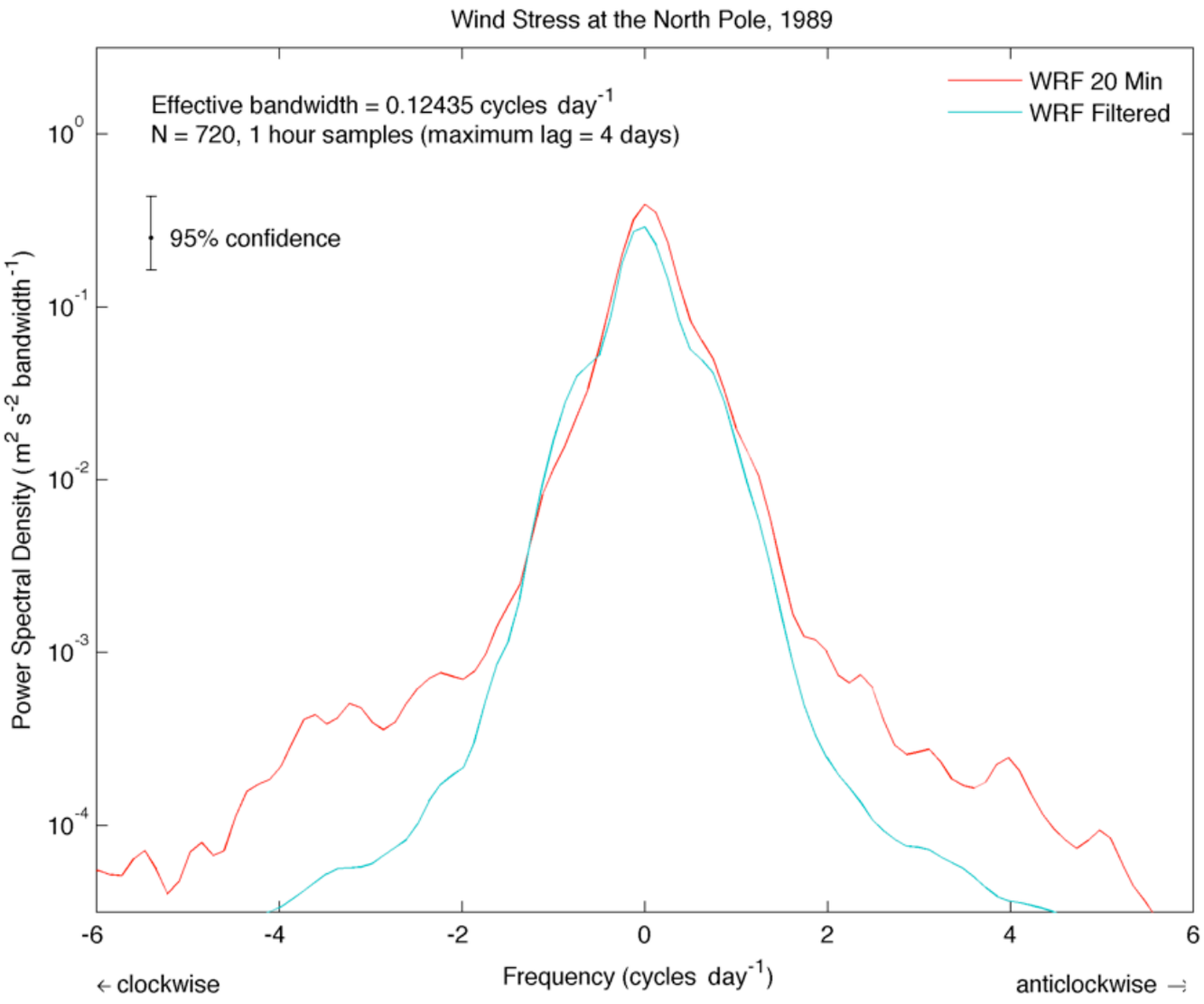
Developing a suitable drift metric

Regional model testbed: The inertia example



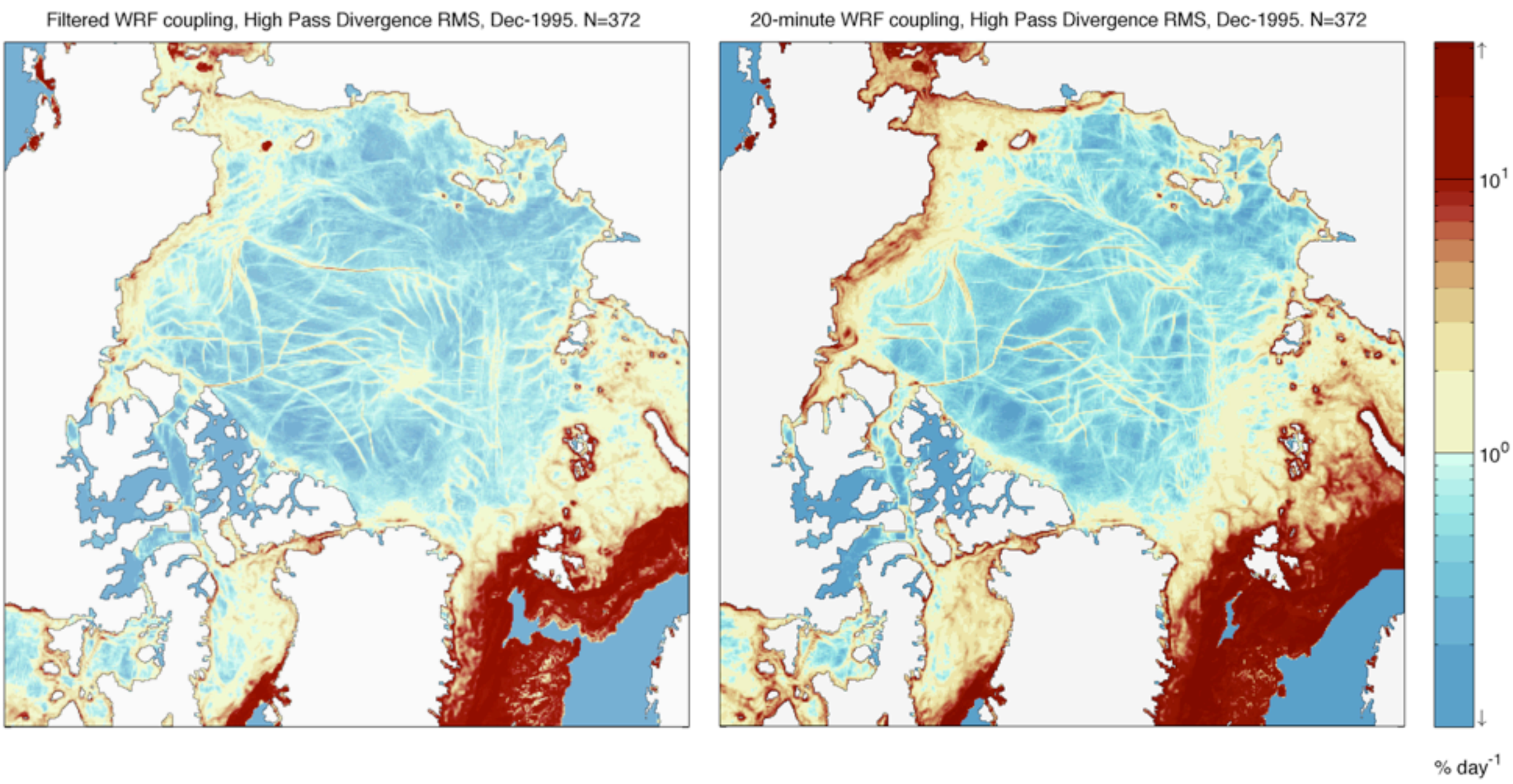
Low ice velocity and resonance

Regional model testbed: Some diagnostics



A framework for testing the influence of z* coordinates on sea ice drift

Regional model testbed: Some diagnostics



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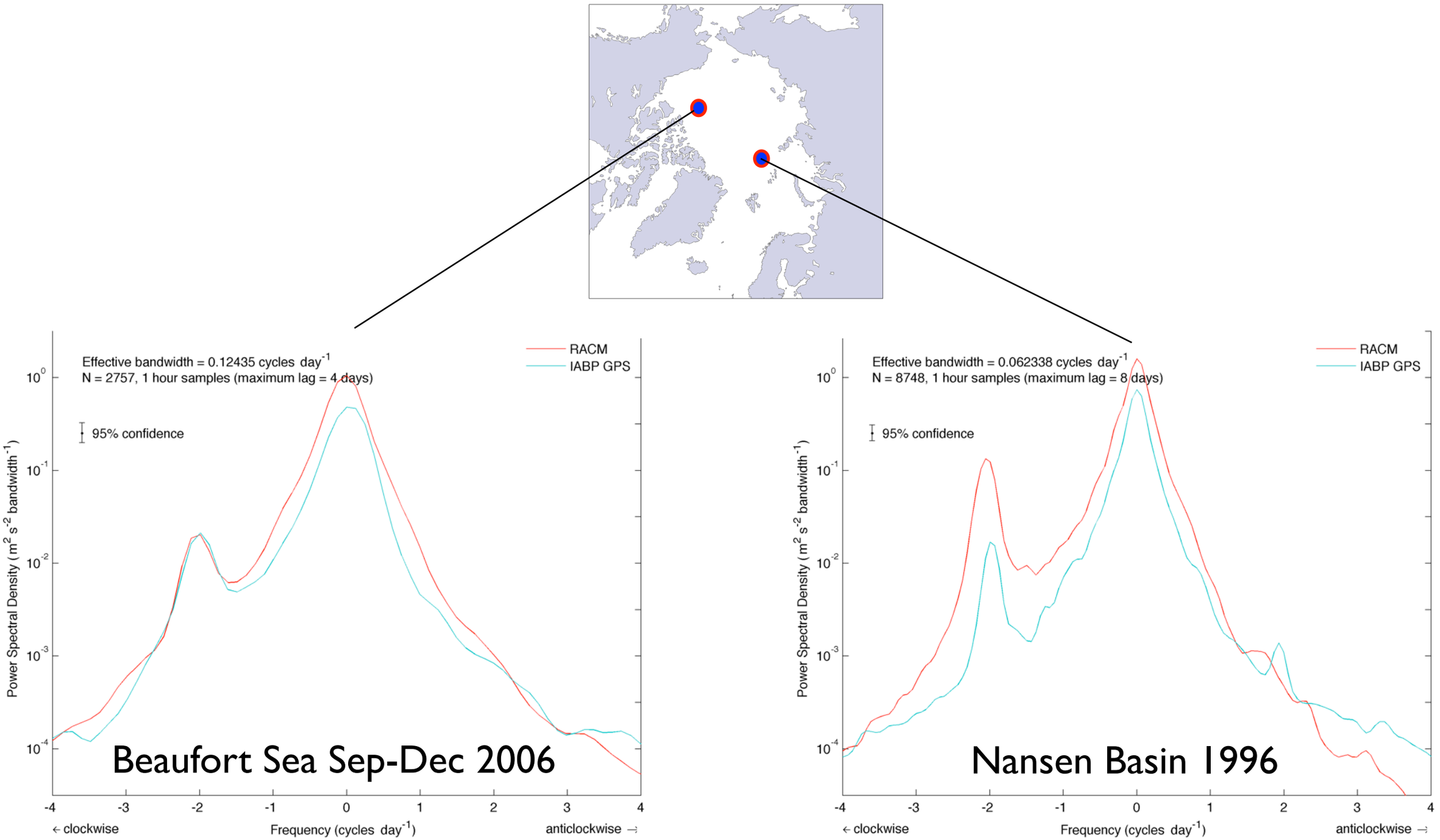
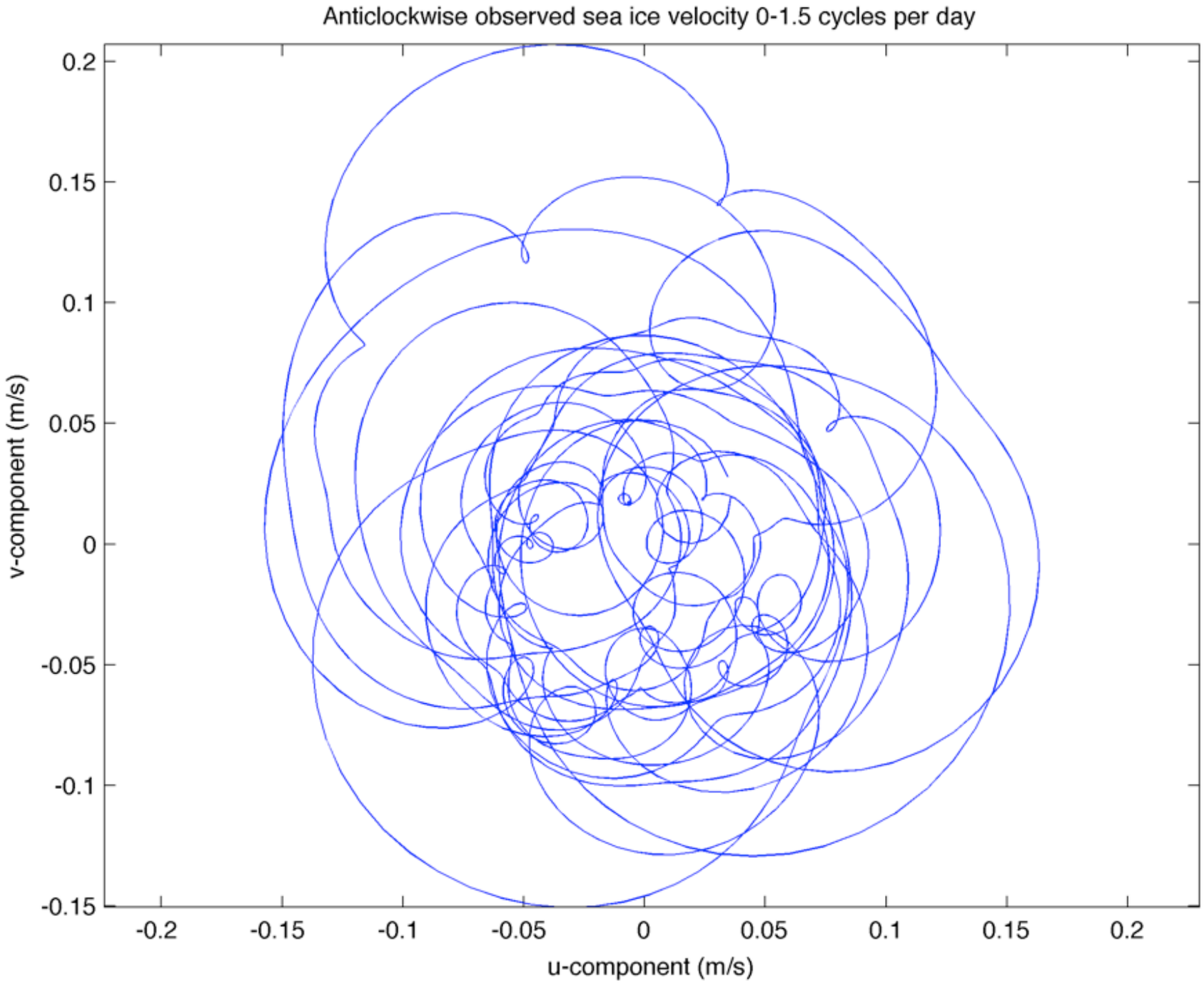


RASM drift power

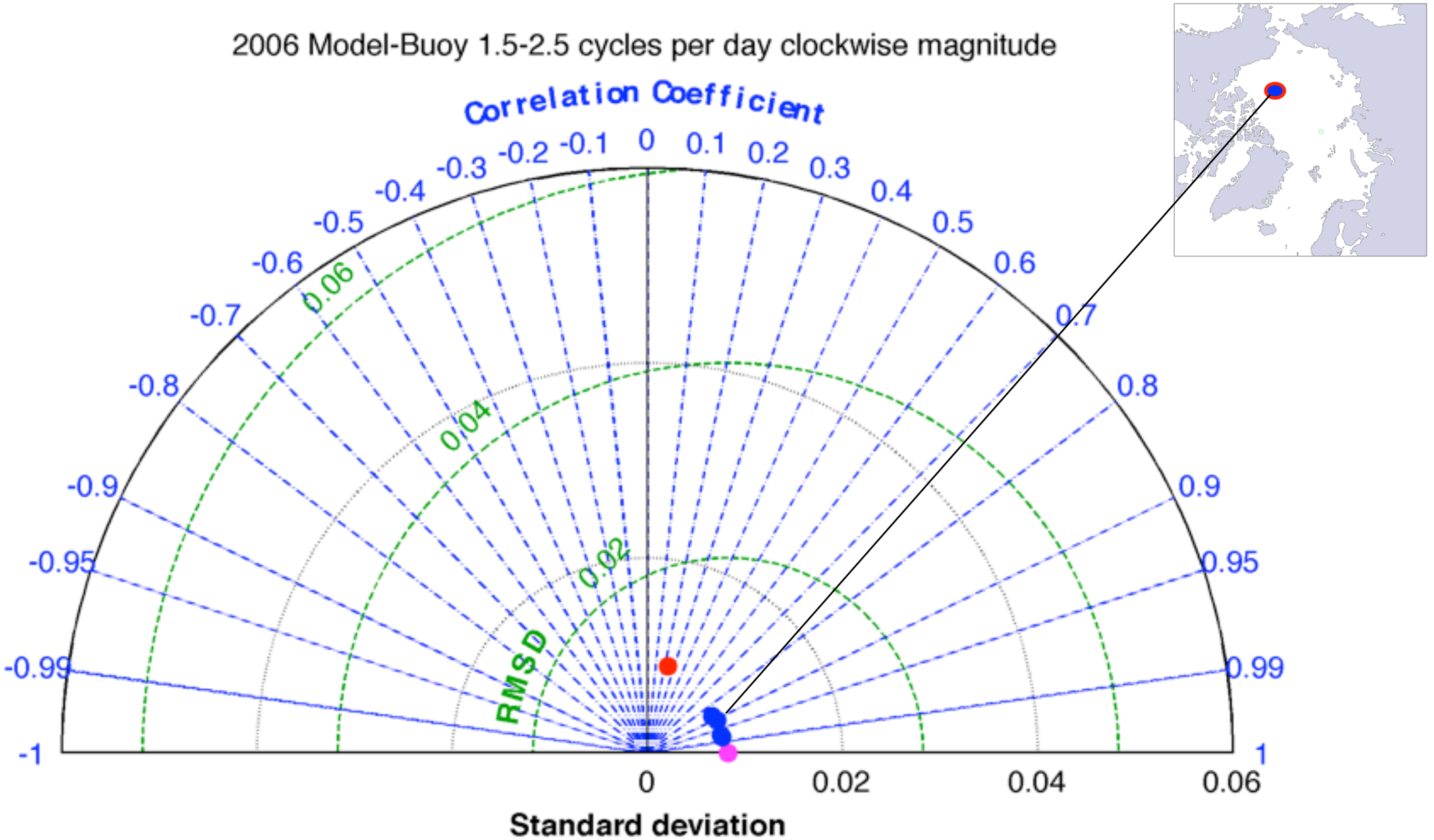
Regional model testbed: The inertia example

Phase space Sept-Dec 2006, $0 \leq \frac{\omega_j}{2\pi} \leq 1.5$

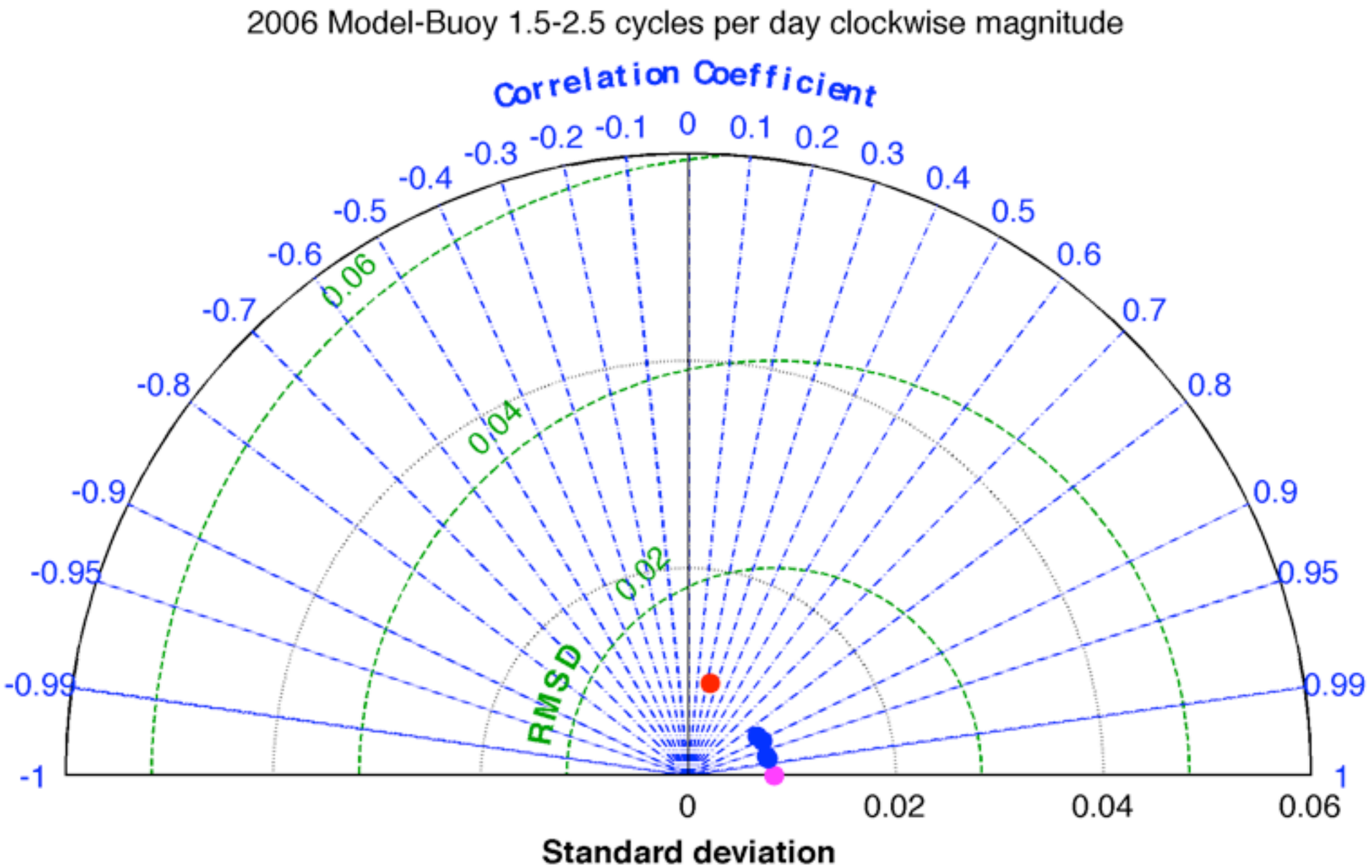


Developing a suitable drift metric

A wavelet approach to drift metrics



A wavelet approach to drift metrics



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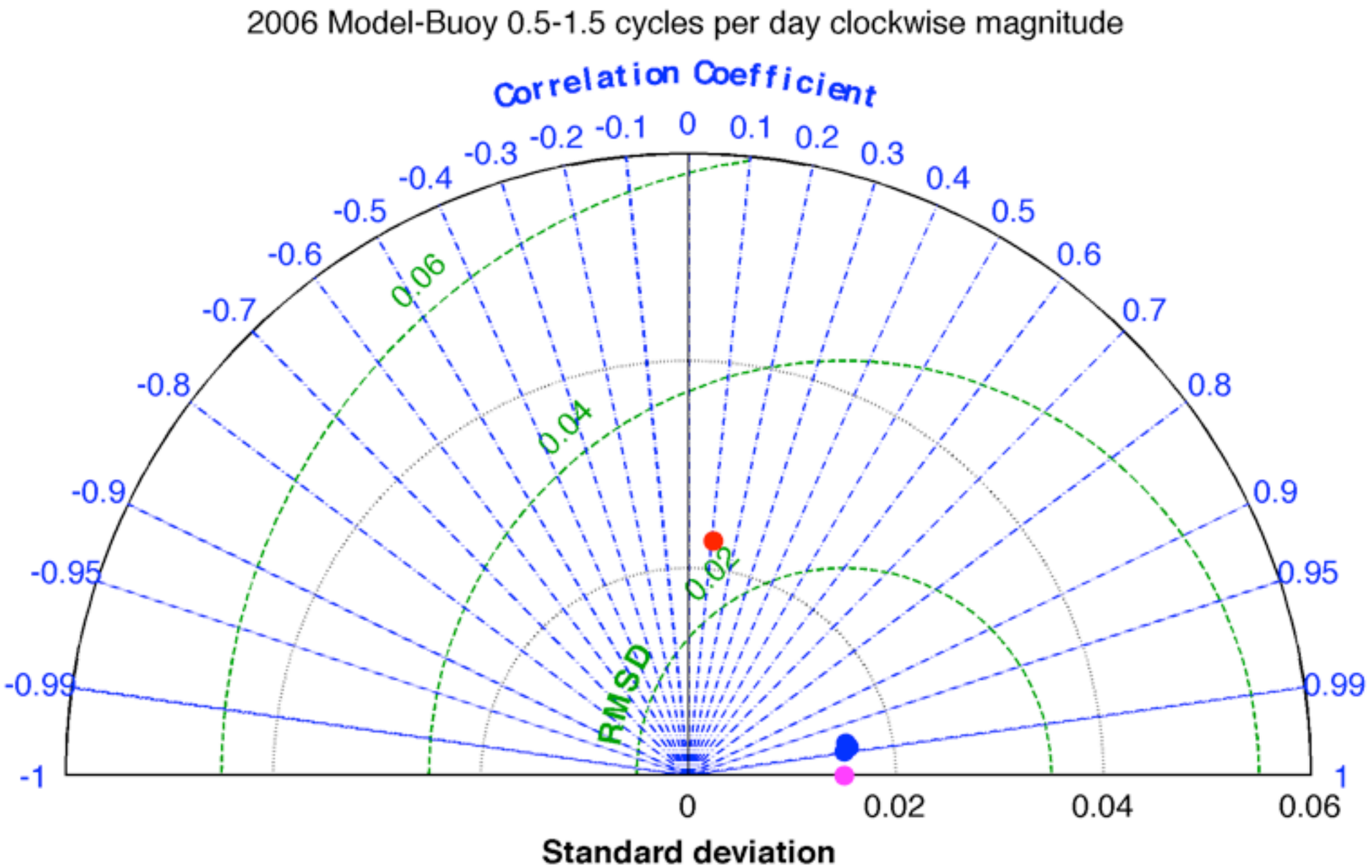

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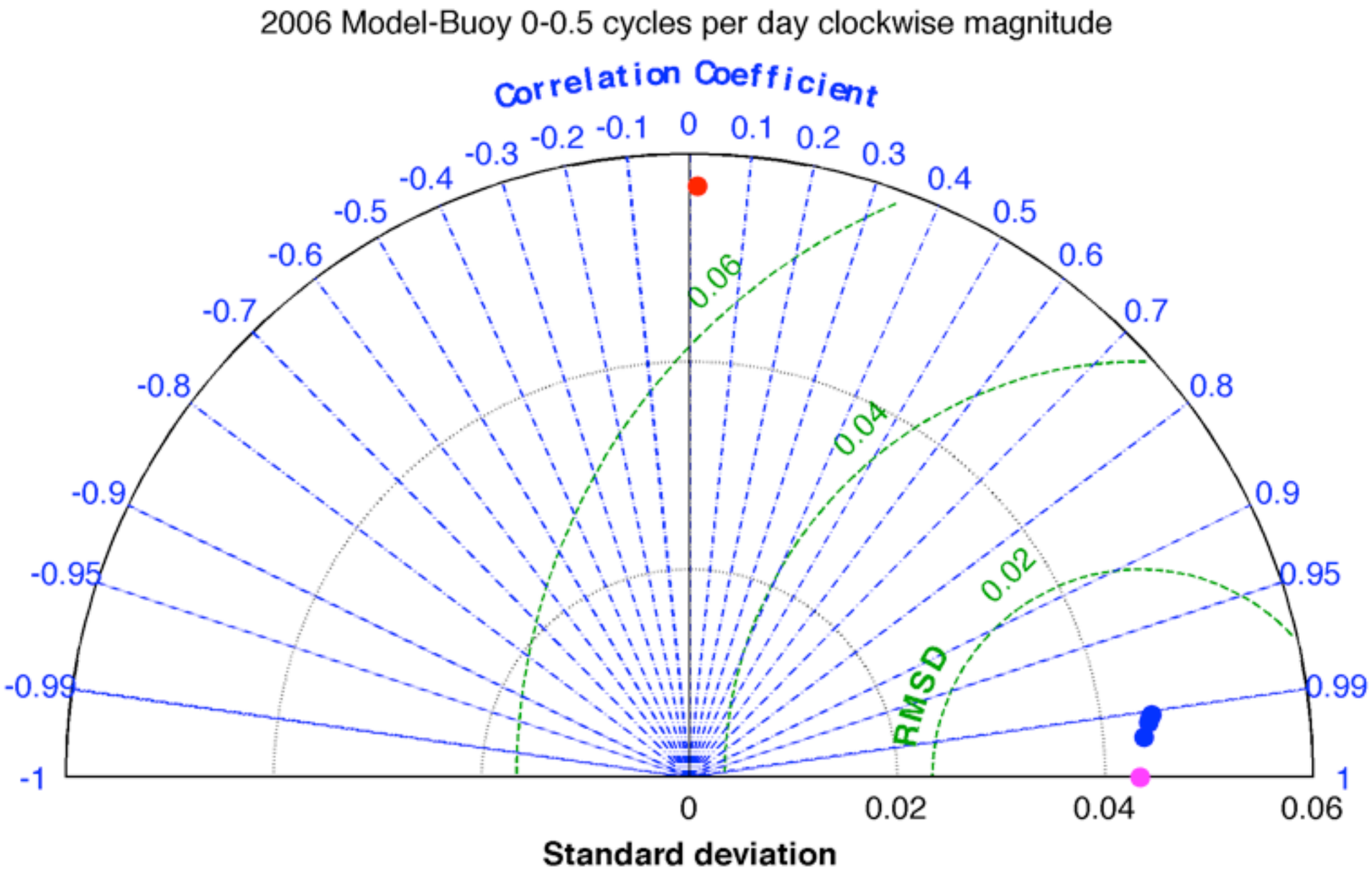
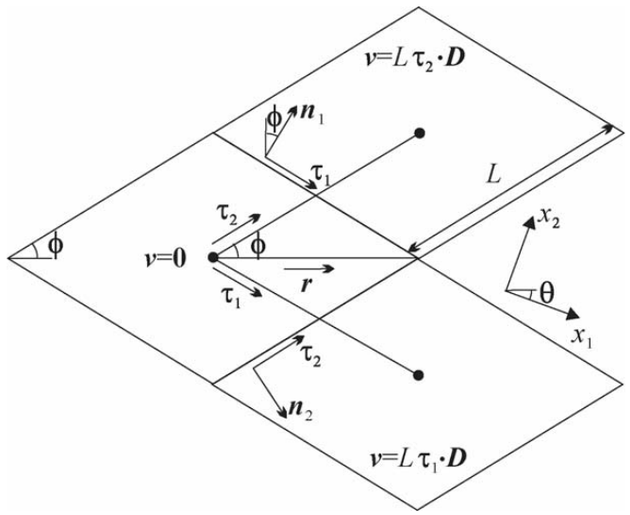


Conclusion: Metric Score Card

Method	Variability	Skill	Uncertainty [observations]	Uncertainty [simulation]
Fourier PSD	✗	✗	□	□
Rotary wavelet power	✔	□	✗	✗
Rotary wavelet filter	✔	□	✗	✗
Rotary wavelet Taylor Diag	✔	✔	✔	✔

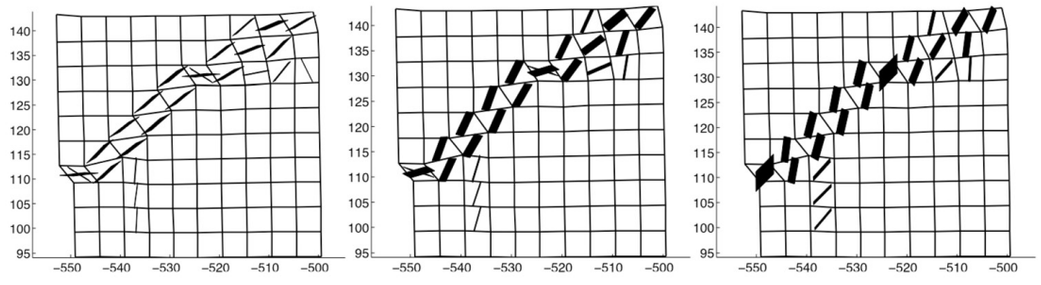
Large-Scale Ice and Ocean Dynamics: Testing new rheologies

– "Diamond Rheology": Michael Tsamados and Daniel Feltham



Wilchinsky, A. V., and D. L. Feltham, 2006: Modelling the rheology of sea ice as a collection of diamond-shaped floes. J Non-Newton Fluid, 138, 22-32.

– Elastic-Decohesive Rheology – Following Shreyer, Sulsky et al.



(a) τ_{sf} = 10 kPa (b) τ_{sf} = 20 kPa (c) τ_{sf} = 40 kPa

Schreyer, H. L., D. L. Sulsky, L. B. Munday, M. D. Coon, and R. Kwok, 2006: Elastic-decohesive constitutive model for sea ice. J Geophys Res-Oceans, 111

Large-Scale Ice and Ocean Dynamics: Opening to a discussion

- Can we simulate inertial oscillations?

- A plan for complementary regional and global modeling towards quantifying the relative importance of tides, inertia, eddies, rheology as against other factors?

- Aside from these topics, what other factors are seen as being important for large-scale ice and ocean dynamics and their influence on boundary layer processes?